Designing a Measuring and Monitoring soil moisture smart farming system using IoT devices for smart rural farming.

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1 Introduction

Agriculture plays an important role in the South African economy. According to Statistics and Economic Analysis (2017) agriculture remains a significant employment provider especially in the rural areas and earner of foreign exchange. It also ensures food security. Therefore, farmers need to take care of soil moisture, to produce a high quality of crop production as crops help in the assurance of food security.

According to (Vani, Rao et al. 2016) soil moisture information plays a significant role in agriculture production and environmental monitoring. Smart farming sensors on agricultural field and combination of smart farming equipment alongside big data analytics would help farmers to be able to improve crop yields and utilize water and thus wastage of any kind would be decreased to a remarkable level (Nayyar and Puri,2016). Hence the main goal of this study is to develop a smart farming system for measuring and monitoring soil moisture using the internet of things (IoT) devices to alert crop farmers about soil moisture.

The chapter begins with a brief background of the study in Section 2. Section 3 address the research problem statement. Followed by Section 4 that explains the key concept central to the study. The research aim is stated in Section 5. Furthermore, the objectives of the study are formulated in Section 6. An overview of the research methodology is given in Section 7. The participants of the study are introduced in Section 8. Section 9 will discuss data collection. Data analysis is explained in Section 10. The rigour, validity and reliability outlined in Section 11. The ethical considerations clear elaborated in Section 12. Section 13 will provide a chapter layout of the study. Section 14 will provide an executive summary.

2 Background to study

Despite the perception individuals may have about the agriculture process, the reality is that today's agriculture industry is data centred, precise and more brilliant than at any other time (Ayaz, Ammad-Uddin et al. 2019). Therefore, the rapid development of the Internet of Things (IoT) based technologies redesigned pretty much every industry. Furthermore, the revolutionary changes are changing the existing agriculture methods and creating new opportunities along with a range of challenges (Ayaz, Ammad-Uddin et al. 2019).

The reason for this study is to help agriculture farmers to improve and combine their old traditional farming practices and methods with technology, to what we call smart farming. Hence a measuring and monitoring soil moisture smart farming system will be designed and developed in this study using the internet of things (IoT) devices.

3 Problem statement

According to Laurenzi (2018), water is an essential resource for farmers growing any types of crop. Without enough water in the soil, the quality of the crops could be compromised and even endanger the livelihood of the crops (Laurenzi,2018). Soil moisture is therefore vital for crop production. According to Institution (2020), as the moisture availability in the soil declines, the normal function and growth of crops are disrupted causing the crop yields to decrease. Soil moisture is also impacted by climate change.

Measuring the soil moisture (high or low moisture level) without devices can be a challenge for farmers growing crops. Hence, crops are often given a huge amount of water or less amount of water (Laurenzi,2018).

Too much moisture in crops and the soil can have negative effects on the agriculture efforts including excessive soil erosion taking away soil nutrients, loss of seeds that are washed away by excessive water and decrease in crop quality (Laurenzi,2018). Additionally, sometimes it is difficult for farmers to realise soil dehydration or low soil moisture and this leads to negative effects on the crops yield because crops need the soil that is moist to fully absorb the nutrients in it (Institution,2020).

Addressing this problem will have practical benefits for the agricultural sector and human beings because agriculture is a crucial sector globally for ensuring food security whereby the crop production and yield contributes a lot in agriculture food security. Also, the health of crops is important and crops health relies upon an adequate supply of moisture and soil nutrients (Institution,2020).

The research will be conducted to design and develop a measuring and monitoring soil moisture smart farming system based on internet of things (IoT) devices to visualise data, make recommendations and alert the farmers about soil moisture levels and soil dehydration.

Research questions of the study are as follows:

1. What are the challenges that farmers face regarding soil moisture?
2. How to improve soil moisture issues using IoT devices?
3. What effect does soil moisture have on crops yield or quality?
4. Will a soil moisture smart farming system empower and help farmers?
5. What are the advantages and disadvantages of IoT in agriculture?
6. How does a soil moisture sensor work?

4 Key concepts of the study

4.1 Agriculture

According to Geographic (2020), agriculture is the art and science of cultivating the soil, growing yields and raising livestock. It incorporates the planning of plant and animal products for individuals to utilize and their dispersion to business sectors. Agriculture gives most of the world's food and fabrics. It plays a significant role in the economic development process and contributes significantly to household food security. Even though agriculture plays an important role in the world it also has its challenges such as demographic changes, land management and weather changes. (Geographic, 2020).

Therefore, in this study, the agriculture sector that will be examined is crop farming field.

4.2 Soil moisture

According to NASA's Earth Science Office, soil moisture implies various things in various disciplines. Therefore, a farmer idea of soil moisture is not the same as that of a water resource manager or a weather forecaster. For the most part, in any case, soil moisture is the water that is held in the spaces between soil particles. Furthermore, surface soil moisture is the water that is in the upper 10 cm of soil, though root zone soil moisture is the water that is accessible to plants, which is commonly viewed as in the upper 200 cm of soil. (NASA,1999).

In this study, the soil moisture that will be examined is the one that falls in farming concepts for crop production.

4.3 Internet of things (IoT)

The Internet of Things truly meets up with the association of sensors and machines. In other words, the genuine worth that the Internet of Things makes is at the crossing point of gathering data and utilizing it. All the data accumulated by all the sensors in the world is not worth a whole if there is not a foundation set up to analyse it in real-time. Hence, cloud-based applications are the way to utilizing utilized information. The Internet of Things does not work without cloud-based applications to decipher and transmit the information originating from every one of these sensors. The cloud is the thing that empowers the applications to go to work for you whenever, anyplace. (Burrus,2018).

To a large extent, this is supported by (Santens,2001) guide to the Internet of Things, where any collaboration with a connected object has the capability of teaching something new to each associated object, and the tremendous scaling of networked machine learning turns out to be

practically unbelievable. Additionally, IoT based agricultural convergence technology (Lee et al, 2013) makes high value as far as quality and expanded production and reduces the burden on farmers inadequate way.

5 Research aim

To design and develop a measuring and monitoring soil moisture smart farming system using the internet of things (IoT) devices for farmers.

6 Research objectives

The following are the research objectives that apply to the study:

6.1 Primary objectives

The primary objective of this study is to design and develop a measuring and monitoring soil moisture smart farming system using internet of things (IoT) devices that will visualise data, make recommendations and alert the farmers about soil moisture levels and soil dehydration.

6.2 Secondary objectives

The second objective of this study is to collect system analysis and design requirements, determine IoT devices and establish ways to build the soil moisture smart farming system.

6.2.1.1 Theoretical Objectives

The theoretical objectives of this study are as follows:

- to understand the problem context;
- to develop an understating about soil moisture concepts;
- to gain an understanding of IoT technology devices;
- to gain knowledge about cloud computing platforms that will help visualise live data;
- to gain knowledge about how soil moisture sensors work;
- to understand soil moisture levels;
- to examine different literature papers with similar concepts to this study; and
- to establish information from the literature that can be used in this study.

6.2.1.2 Empirical Objectives

The empirical objective of this study is as follows:

- to use IOT technology devices to develop measuring and monitoring soil moisture system; and
- to visualize data received from the artefact.

7 Research methodology

The research approach applied to this study is a qualitative approach. UKEssays (2017) defines qualitative approach as an approach that is drawn from the constructivist paradigm. Feilzer (2010) expand the definition further, a qualitative approach is normally utilized for examining social phenomena instead of seeking a causative relationship between the established variable. For this study, the applicable research methodology is design science research (DSR). According to (Hevner, March et al. 2004) when conducting DSR, an artefact is developed. In this study, the artefact is a soil moisture smart farming system. Therefore, DSR as the methodology is best suited for this study. Methods and principles for DSR will be followed that will aid the researcher to firstly understand the problem context and to design and evaluate the artefact. The methodology does not only allow the researcher to develop an artefact but also learn about the creation of the artefact by following the design science knowledge (descriptive and prescriptive) knowledge principles (Gregor and Hevner 2013). The research is exploratory because it is best for the researcher to know the user requirements for the system to avoid building something that is not relevant to the user needs.

The data in this study will be collected through interviews to gather requirements for the design of the measuring and monitoring soil moisture smart farming system before the development phase. The data collected will be analysed using a coding strategy.

8 Selection of participants

The participants of this research are agriculture farmers and individuals working at the department of agriculture with crops field. Reason for the selection of these participants is because they have greater knowledge about agriculture hence, they will be able to provide accurate and valid information needed for this study.

8.1.1.1 Sampling size and technique

Interviews will be conducted to gather data in this study. The number of participants will be determined by data saturation as this is a qualitative study.

8.1.1.2 Inclusion criteria

The participants allowed to partake in this study are farmers that are 18 years old or older.

8.1.1.3 Exclusion criteria

Children and other individuals who are not farmers or working at the department of agriculture will be excluded to partake in the study.

8.2 Recruitment of participants

The researcher will contact farmers around Vanderbijlpark and explain the aim and objective of the study as well as the ethical considerations and obtain consent to conduct an interview.

8.3 Process of obtaining informed consent

To ensure the participants partake voluntarily, a consent form will be given to participants to complete before they can partake in the study. Care will be taken to keep participants information private and to portray their views as they intended.

9 Data collection

Interviews will be conducted to collect data from the participants to be able to explore the experiences, views, opinions and beliefs of the participants on the matter. The interviews will be individual. The interviews will take the form of unstructured interviews with open-ended questions to allow interviewees to respond in any way seems appropriate. Open-ended questions will enable the participants to elaborate on questions and thus, provide rich information not limited by closed questions.

9.1.1.1 Development of data collection tool

For the researcher to be able to conduct the interview, ethical principles as well as principles and guidelines of developing an interview will be followed.

According to Driscoll (2011), an interview is defined as as the data collection technique of "*asking participants questions in a one on one or small group setting*".

The first step will be selecting the interviewees. Then after an interview template will be downloaded or manually conducted to start writing important interview contents. The interviews will be individual. The interviews will take the form of unstructured interviews with open-ended questions.

The interview questions will be based on the content of the study. Additionally, according to Bentley (2007), these following things will be avoided when conducting the interviews questions:

- Complex questions.
- Threatening questions.
- Use of opinions as part of the question.
- Unclear language.
- Questions on another context than that of the study.
- Loaded questions.
- Leading questions.
- Biased questions.

10 Data Analysis

Coding analysis will be used in this study to analyse the data collected. Firstly, the data will be organized and prepared and coded. During coding and analysis, the researcher will conceptualize, classify, categorize data and identify themes, patterns, relationships, sequences and difference in the data. Furthermore, the researcher will connect and interrelate data also interpret, create explanatory accounts and lastly provide data meaning. Braun and Clarke (2006) define codes as "*Pithy labels identifying what is of interest in the data*" and defines themes as "*A common, recurring pattern across a dataset, clustered around a central organising concept*".

11 Rigour / Validity & reliability

To ensure rigorous research of the study the design science guidelines will be followed and applied. The research will be evaluated based on the principles of design science research.

According to Gregor and Hevner (2013) the artefact should be evaluated based on the following design science principles to ensure rigour, validity and reliability:

- Usefulness
- Validity
- Utility
- Quality
- Efficacy
    - Effectiveness
    - Efficiency

12 Ethical considerations

According to Driscoll (2011), ethical consideration includes:

12.1 Permission and informed consent

- to ensure ethical clearance have been granted for this study; and
- to ensure informed consent is obtained from all the participants.

12.2 Anonymity

- to ensure to inform all the participants about their anonymity during the study.

12.3 Confidentiality

- to ensure participant privacy not revealed without their consent.

12.4 Other ethical considerations

According to Gregor and Hevner (2013) design science, ethical considerations include:

- to ensure that your own biased opinions do not interfere with the study;
- to ensure participants that are beneficial to the study;
- to ensure the privacy of users of the artefact;
- to ensure the gathered information is accurate;
- to ensure that the intellectual property rights are defined and adhered to; and
- to ensure access to the artefact and gathered information appropriately controlled.

13 Chapter layout

- **Chapter 1: Introduction and motivation for the study-** This chapter will introduce and provide a background overview of the study, explains why it is necessary.
- **Chapter 2: Research methodology-** This chapter will explain the research methods and methodology applicable to the study.
- **Chapter 3: Literature review-** This chapter will provide a comprehensive summary of previous existing literature relating to key concepts of this study.
- **Chapter 4: Empirical report-** This chapter will discuss the empirical analysis findings regarding the empirical objectives.
- **Chapter 5: Summary and conclusion-** This chapter will provide an overview summary of the study and conclude the study.

14 Executive Summary

This chapter served as the introduction of the study. The chapter discussed the purpose of the study including the aim and the objective of the study, whereby the research aim is to design and develop a measuring and mentoring soil moisture smart farming system using internet of things (IoT) devices for farmers. It also justified the research problem along with the research questions aligned to the research aim. Furthermore, the key concepts of the study where proper defined followed by the research approach which includes the research methodology, participants, data collection and data analysis methodologies. The research methodology of the study is design science, matching the purposes of the research of designing an artefact. The research approach is qualitative research that will use interviews to collect data and use the coding strategy to analyse collected data.

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